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The comparison of the effectiveness of the lowest supply lowest cost (LSLC) algorithm and the exponential approach algorithm in transportation problems

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ABSTRACT

Transportation problems are one of the particular forms that often appear in linear programs, one of which is the distribution of goods. A transportation method is needed to determine the optimal result, namely, the minimum cost from source to destination with all demand and supply fulfilled. There are several methods, one of which is the Lowest Supply Lowest Cost Method (LSLC) and the Exponential Approach Method (PE). Both methods are made in a MATLAB program, generating a script that calculates the algorithm's time complexity. Using the function notation, the Big-O Algorithm complexity of the Lowest Supply Lowest Cost method is more efficient than the Exponential Approach Method algorithm. At the same time, the optimal result for the minimum cost between the two methods is obtained by using the Exponential Approach Method.

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INTRODUCTION

The transportation problem of a company requires minimal transportation costs so that the company gets a maximum profit and the demand is met. Therefore, to solve this problem, a transportation method is needed. The method used to regulate the distribution of sources that provide the same product to destinations optimally (Eddy, 2008). There are various methods of transportation with or without finding an initial feasible solution. Initially, the minimal cost transportation method was developed by Hitchcock (1941), then with the development of transportation methods carried out by researchers, such as the method derived from the simplex algorithm developed by Dantzig (1951) then Charnes et al. (1954). Until now, there are several methods to find an initial feasible solution such as North West Corner Method, Least Cost Method, Vogel's Approximation Method, and optimality test using Stepping Stone Method and Modified Distribution Method.

Then several methods were re-invented to find a more straightforward solution to transportation problems without looking for an initial feasible solution, such as the Exponential Approach method and the Lowest Supply Lowest Cost method. The Lowest Supply Lowest Cost method is a new method researched by Kantharaj (2018), while Vannan & Rekha (2013) developed the Exponential Approach (PE) method. Furthermore, Notiragayu et al. (2019), compare the Exponential Approach (PE) method and the combination of VAM - MODI for the number of requests that greater than the amount of supply. VAM-MODI method is more optimal because it gets a minimum cost. However, the PE method uses an efficient shortcut procedure (Notiragayu et al., 2019). Due to technological advances that are growing, in this research, the authors are interested in making comparisons between the Lowest Supply Lowest Cost method and the Exponential Approach method. Moreover, comparing the time complexity of the algorithm program script of the Lowest Supply Lowest Cost and the Exponential Approach algorithm using notation *Big*-O (Subandijo, 2011).

This research aims to compare the effectiveness of the LSLC algorithm and the exponential approach algorithm using the notation function *Big*-O for transportation problems.

METHOD

There are various methods for solving transportation problems from the initial discovery of transportation methods, and all provide initial solutions that are close to the optimum solution of transportation problems (Taha, 2002). In this research, two transportation methods will be discussed without looking for an initial solution. However, the optimum solution is immediately obtained, namely the Lowest Supply Lowest Cost (LSLC) Method and the Exponential Approach Method (PE).

The LSLC method has easy steps and also directly obtains the optimal solution with few iterations. Similar to the LSLC method, the PE method directly obtains the optimal solution in its calculations without having to find a feasible solution initially (Vannan & Rekha, 2013), but with longer steps and iterations than the Lowest Supply Lowest Cost (LSLC) method (Kantharaj, 2018). Both methods are made by algorithms using the MATLAB programming language, which is software for programming, and matrix-based mathematics, by optimizing to get the optimal solution. The maximum and minimum values are obtained by using the numerical method. The algorithm that is used is iterative, which is an iterative process (Widiarsono, 2005).

The following theorems are used to calculate the time complexity of the algorithms of the two methods (Levitin, 2012).

Theorem 1. *Big*-O (Munir, 2006): If $T_1(n) = O\big(f(n)\big)$ and $T_2(n) = O\big(g(n)\big)$, then

1. $T_1(n) + T_2(n) = O\Big(max\big(f(n), g(n)\big)\Big)$
2. $T_1(n)T_2(n) = O\big(f(n)\big)O\big(g(n)\big) = O\big(f(n)g(n)\big)$
3. $O\big(cf(n)\big) = O\big(f(n)\big)$, c is a constant
4. $f(n) = O\big(f(n)\big)$

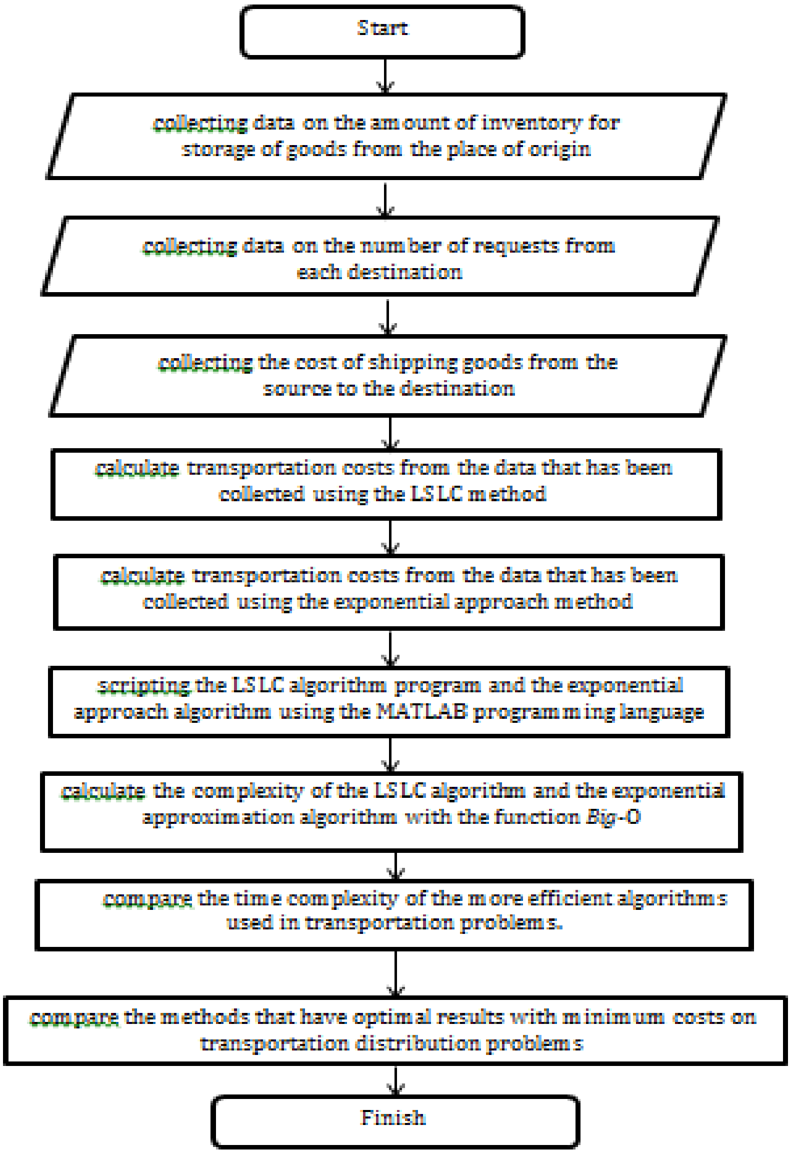

Figure 1. Research design

This research was conducted using a literature study, namely studying the books contained in the Mathematics Department library, journals, and internet access that support the research process and secondary data obtained from the BULOG Branch Office of the Lampung Regional Office.

The research procedures are as follows; first, collect data on the amount of inventory for storage of goods from the place of origin, data on the number of requests from each destination, and the cost of shipping goods from the source to the destination. Second, calculate transportation costs from the data that has been collected using the LSLC method and the exponential approach method. Third step, scripting the LSLC algorithm program and the exponential approach algorithm using the MATLAB programming language. Fourth, calculate the complexity of the LSLC algorithm and the exponential approximation algorithm with the function *Big*-O. Next, compare the methods with optimal results with minimum costs on transportation distribution problems, and compare the time complexity of the more efficient algorithms used in transportation problems.

RESULTS AND DISCUSSION

The data used in the transportation problems is the cost of sending rice from the Lampung Regional Office warehouse to the North Lampung Branch Office warehouse, which can be seen in the following Table 1.

Table 1. Transportation Problems

Destination / Source	Distribution Costs to Destination Warehouses (Rp/Ton)			Inventory (tons)
	Pisang Baru	Pekon Wates	Mulang Maya	
Rantai Tijang	280,500	250,750	260,900	650
Campang Raya	350,750	300,500	320,500	850
Garuntang	230,000	290,500	300,250	300
Demand (tons)	600	600	600	1800

3.1 Lowest Supply Lowest Cost Method (LSLC)

The initial steps are as follows; Determine the smallest inventory value from all sources and determine the most negligible shipping costs from that source to the destination warehouse. Furthermore, the allocation of maximum shipments to the destination city, it is known that the lowest inventory is 300 tons. Next, determine the most negligible shipping cost from the lowest inventory. The minimum fee is Rp 230,000. Finally, allocate the maximum shipment of goods from Garuntang to Pisang Baru, which is 300 tons. The demand for the new banana warehouse is 600 tons. Because it has been filled by 300 tons from Garuntang, the remaining demand that has not been fulfilled is 300 tons. Repeat the initial steps until all supplies and requests are empty so that the optimal results are obtained in the following Table 2.

Table 2. Optimal Solution for Rice Distribution LSLC Method

Destination / Source	Distribution Costs to Destination Warehouses (Rp/ton)			Inventory (tons)
	Pisang Baru	Pekon Wates	Mulang Maya	
Rantai Tijang	280,500	250,750 [600]	260,900 [50]	650
Campang Raya	350,750 [300]	300,500	320,500 [550]	850
Garuntang	230,000 [300]	290,500	300,250	300
Demand (tons)	600	600	600	1800

Total distribution costs are $= (600 \times 250{,}750) + (50 \times 260{,}900) + (300 \times 350{,}750) + (550 \times 320{,}500) + (300 \times 230{,}000) = 150{,}450{,}000 + 13{,}045{,}000 + 105{,}225{,}000 + 176{,}275{,}000 + 69{,}000{,}000 = 513{,}995{,}000$.

3.2 Exponential Approach Method (PE)
The steps are as follows;

Subtracts each row entry in the table by the minimum value of each row so that there is at least 1 zero in each row and subtracts each column entry in the table by the minimum value of each column so that there is at least 1 zero in each column. Then, select the zero that contains cell ij in the table. Next, we count the total number of zeros, excluding the zeros selected from row *i* and column *j*, then sets an exponent penalty (The number of zeros does not include the selected ones). Choose zero for the minimum exponent penalty obtained in the previous step, then allocate the maximum possible number of cell values. Repeat the initial steps until all supplies and requests are empty so that the optimal results are obtained in the following Table 3.

Table 3. Optimal Solution of Rice Distribution Method PE

Destination / Source	Pisang Baru (A)	Pekon Wates (B)	Mulang Maya (C)	Inventory
Rantai Tijang (1)	280,500 [300]	250,750	260,900 [350]	650
Campang Raya (2)	350,750	300,500 [600]	320,500 [250]	850
Garuntang (3)	230,000 [300]	290,500	300,250	300
Demand	600	600	600	1800

Total distribution costs are $= (300 \times 280{,}500) + (350 \times 260{,}900) + (600 \times 300{,}500) + (250 \times 320{,}500) + (300 \times 230{,}000) = 84{,}150{,}000 + 91{,}315{,}000 + 180{,}300{,}000 + 80{,}125{,}000 + 69{,}000{,}000 = 504{,}890{,}000$. The problem is a transportation problem with a balanced case. The following is an example of a calculation for an unbalanced problem (Winston, 2004).

Table 4. Unbalanced Transportation Problem

Destination / Source	Freight Cost ($/Ton) Market 1	Market 2	Market 3	Inventory (ton)
Factory 1	8	5	6	100
Factory 2	15	10	12	120
Factory 3	3	9	10	80
Demand (ton)	110	110	110	

Step the same calculation as issue balanced only in this case there will be market demand that is not met due to the amount of inventory that is lacking. So that the solution obtained by the LSLC method is in the following table 5.

Table 5. LSLC Method Solution Unbalanced Transportation Problem

Destination / Source	Freight Cost ($/Ton) Market 1	Market 2	Market 3	Inventory (ton)
Factory 1	8	5 [100]	6	100
Factory 2	15	10 [10]	12 [110]	120
Factory 3	3 [80]	9	10	80
Dummy	0 [30]	0	0	30
Demand (ton)	110	110	110	

Total distribution costs are $= (100 \times 5) + (10 \times 10) + (110 \times 12) + (80 \times 3) = 500 + 100 + 1320 + 240 = 2160$. With Market 1's demand of 30 tons not being met.

Similar to the LSLC method, the optimal results for the PE method are shown in the following table 6.

Table 6. Solution of PE Method Unbalanced Transportation Problem

Source \ Destination	Freight Cost ($/Ton) Market 1		Market 2		Market 3		Inventory (ton)
Factory 1	8	30	5		6	70	100
Factory 2	15		10	110	12	10	120
Factory 3	3	80	9		10		80
Dummy	0		0		0	30	30
Demand (ton)	110		110		110		

Total distribution costs are $= (30 \times 8) + (70 \times 6) + (110 \times 10) + (10 \times 12) + (80 \times 3) = 240 + 420 + 1100 + 120 + 240 = 2120$. With the demand to Market 3 unfulfilled as much as 30 tons.

3.3 Making Program Scripts for the Two Methods

The following is a flowchart of the PE and LSLC methods to produce the process in the program;

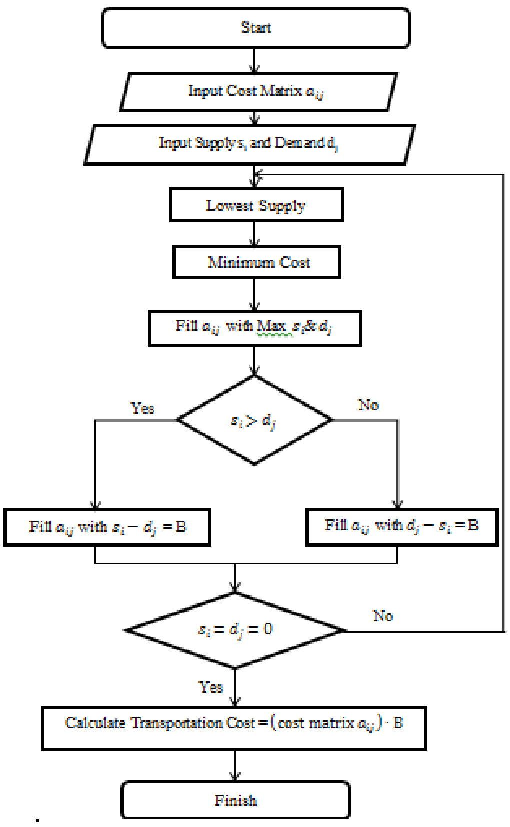

Figure 2. Flowchart of LSLC Method

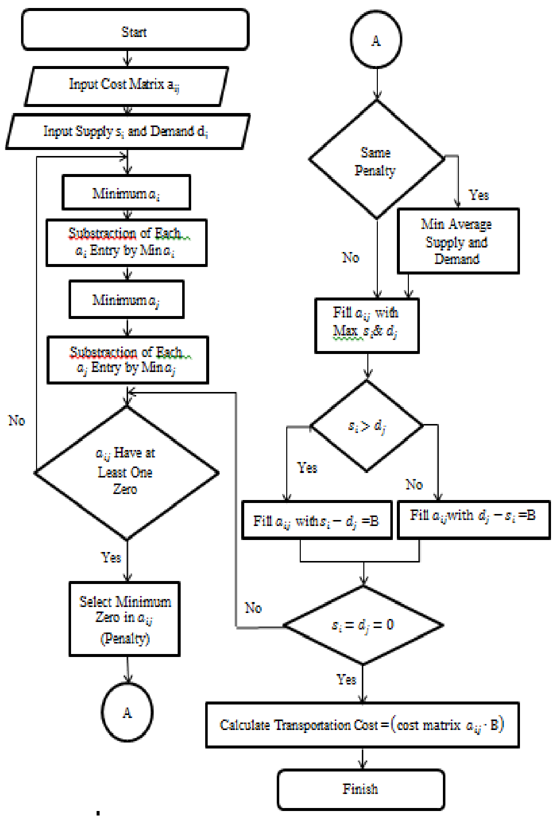

Figure 3. Flowchart of PE Method

As in Figure 2, the steps of the algorithm of Lowest Supply Lowest Cost are as follows, first, find the smallest inventory among the given inventory and must be greater than 0, the second step for the row that has the smallest inventory in the first step, find the lowest cost in the row entry, the third step on the cost, allocate the maximum possible inventory unit to meet the demand requirements, the fourth step cross out the remaining row or column elements, i.e., the supply or demand value becomes 0, then repeat steps 1-4 until all supplies and demand are empty and lastly calculate the total transportation costs as the number of products from the allocation and transportation costs respectively.

As in Figure 3, the steps of the Exponential Approach algorithm are as follows, first, find the minimum price for each column and row in the transportation table. The second step, subtracts each row entry from the transport table from the respective row minimum. Then subtracts each column entry of the transport table from the respective minimum column. Respectively, each row and column will have at least one zero. The third step, selects the zeros contained in cell *ij* in the table. Counts the total number of zeros presented (excluding selected zeros) in row *i* and column *j*. Set an exponent penalty (sum of zeros in row *i* and column *j* excluding selected zeros). Repeat the procedure for all zeros in the table. The fourth step, selects the zeros for the minimum penalty exponent obtained from the third step and allocates the cell values with the maximum possible number. If the exponential penalty is the same for each cell, then first check the demand and supply values, calculate the average value and assign an allocation to the lowest average value. If it remains the same, check the appropriate values in the rows and columns, select the minimum. The fifth step, marks the row or column (where supply or demand becomes zero) not to be included in the following calculation. The sixth step, check that each resulting table has at least one zero in each column and each row. If not, go back to step two, then repeat step three to step six until all demand is satisfied and all supplies are exhausted, the last one is calculating the optimum cost.

3.4 Time Complexity Calculation with *Big*-O

The calculation of the time complexity of the program script is carried out by calculating *Big*-O for each instruction entered in the program script, then applying the function *Big*-O. Note: for entry value, arithmetic operations, read, write, conditioning, access array (read, write, delete, edit), each is worth *O(1)*.

The calculation of the LSLC method program script and the PE method program script in the input and output process is filled in by *O(1)*. So, it will be calculated *Big*-O in the process in the program. Method of calculation: while a command is $(n-1)$ and "for" is n, while if is *O(1)*. If there is a command in the command, then the multiplication operation is performed. Otherwise, all the commands are added. The method of multiplication and addition is explained in the Theorem *Big*-O.

So that the results of the complexity of the algorithm with the following *Big*-O LSLC script are obtained;

$$T(n) = T(n_1) + T(n_2) + T(n_3) + T(n_4) + T(n_5) + T(n_6) + T(n_7) + T(n_8)$$
$$= O(1) + O(1) + O(1) + O(1) + O(1) + O(1) + O(n) + O(1)$$
$$= O\big((1{,}1)\big) + \big((O1.1)\big) + \big((O1.1)\big) + O\big((n,1)\big)$$
$$= O(1) + O(1) + O(1) + O(n)$$
$$= O\big((1{,}1)\big) + O1\big((,n)\big)$$
$$= O(1) + O(n) = O\big((1,n)\big) = O(n)$$
$$T(n) = O(n)$$

While the PE method results in the complexity of the algorithm with the following Big-O;

$$T(n) = T(n_{29}) + T(n_{14}) + T(n_{18}) + T(n_{17}) + T(n_{28}) + T(n_{30})$$
$$= O(1) + O(n^4) + O(1) + O(n^2) + O(n^2) + O(1)$$
$$= O\big(max(1, n^4)\big) + O\big(max(1, n^2)\big) + O\big(max(1, n^2)\big)$$
$$= O(n^4) + O(n^2) + O(n^2)$$
$$= O\big(max(n^4, n^2)\big) + O(n^2)$$
$$= O(n^4) + O(n^2) = O\big(max(n^4, n^2)\big) = O(n^4)$$
$$T(n) = O(n^4)$$

Where, $T(n_{29})$ and $T(n_{30})$ are inputs, and the other outputs are processed in the program.

So that the time complexity of the LSLC algorithm is $O(n)$ and the exponential approach algorithm is $O(n^4)$.

CONCLUSIONS AND SUGGESTIONS

Based on the results and discussion, it can be concluded that optimal results are obtained with minimum costs for balanced and unbalanced cases, namely the Exponential Approach Method. The time complexity of the algorithm is Lowest Supply Lowest Cost in the class *Big*-O linear $O(n)$, while the Exponential Approach algorithm is in the class *Big*-O polynomial $O(n^4)$. With the command tic; toc; the LSLC method is 0.030283 seconds for balanced cases and 0.027296 seconds for unbalanced cases, and the PE method is 0.041643 seconds for balanced cases and 0.039466 seconds for unbalanced cases. So that the more efficient time complexity is the Method Lowest Supply Lowest Cost with an efficiency class of $O(n)$.

This research can be continued using other alternative algorithms to solve transportation problems, for example Vogel approach method and others.

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